INFLUENCE OF CROP ROTATION AND FERTILIZATION ON WHEAT YIELD IN CONDITIONS OF ERODED SOIL FROM NORTH WESTERN ROMANIA

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Abstract

The paper is based on the research carried out during 2014-2016 on the preluvosoil from Agricultural Research and Development Station Oradea on a land with a slope of 10% and took into account the study of the influence of two types of crop rotation (wheat, maize, oats + clover - clover - wheat - maize) on wheat yield and on water used efficiency of wheat crop. The research was conducted under 4 graduations organic fertilizer (unfertilized, manure 25 t/ha, manure 50 t/ha, lupine and lupine + oats) and two graduations of mineral fertilization (N_0P_0; $N_{90}P_{80}K_{60}$. Organic fertilization (used in maize crop) associated with mineral fertilization determined obtaining of higher wheat yield compared with only organic fetilization. The highest yields were obtained in the variant with manure 50 t / ha + $N_{90}P_{80}K_{60}$. Lupine as green manure incorporated into the soil for maize crop determined obtaining of higher gain yield statistically assured compared with variant unfertilized but lower than the gain yield obtained by using manure 25 t / ha. In the crop rotation with clover, has improved the water use efficiency by wheat as compared to wheat-maize crop rotation.

Key words*: winter wheat, fertilizers, crop rotation, lupine, water use efficiency, yield*

INTRODUCTION

Erosion is the detachment process of soil particles (rock), the transport of them to the place of origin and deposited elsewhere.

Erosion causes following:

Soil degradation and loss of productivity: *Changing the physical properties of soil*: soil structure is deteriorating as a consequence of the humus horizon; consequently the porosity decreases, bulk density increases. Soil texture is modified by increasing the proportion of skeleton, being able to bring to the surface the lower horizons, most often have a different texture from the upper horizon; changing relationships by decreasing soil water infiltration and stronger leakage on surface; this causes an accelerated erosion. The amounts of infiltrated and stored water shall be reduced by 20-90% compared with unerodated soils.

Changing the chemical properties of soil: As a result of the erosion the humus and nitrogen content of the soil reduced significantly and lower content of phosphorus.

Changing soil biological activity: Due to reduction of organic matter in these soils biological activity is very diminuated.

The destruction of soils located in valleys. Eroded material is deposited on the slopes of the valley soil and clay and other colloids penetrate uncapilar space and decreasing soil porosity and permeability. If the material is deposited in large quantities on the surface of soil a layer clogged with decreased fertility, especially if it comes from erosion depth forms.

Increasing production costs: By bringing to the surface more compact lower horizons, erosion determined the increases of fuel consumption required to soil tilage.

Other damage caused by erosion is difficulties in land use, flooding, increased drought, environmental pollution. Soil erosion is a powerful factor of disturbing the balance in nature, pollution of the ambient environment.

It is impracticable agriculture without soil loss and efforts made for soil conservation can not totally excluded the erosion process, but it limits at the limits.

MATERIAL AND METHOD

The research was conducted in Oradea, a town located at $45^0 03^{'}$ north latitude and $21^0 56^{'}$ east longitude. Field research is amplased on a hillside with a slope of 10%. Soil profile is as follows: Ap = 24 cm; El= 24-34 cm; Bt_1=34-54 cm; Bt_2= 54-78 cm; Bt/c= 78-95 cm; C= 95-145 cm. On sown field was determine available mineral nitrogen content (N-NH + NO3) of 3.86 ppm, 6.0 ppm, and 88.5 ppm phosphorus content, potassium mobile content, pH value is 5,5. Wilting coefficient had a medium value on 0-75 cm depth and a great value below this depth. Field capacity is medium on the entire depth and water use capacity is high on depth of 0-50 cm and medium on depth of 50-150 cm.

It has placed a research field with following experimental device: Factor A: crop rotation: a1 = wheat-maize; a2 = oats + clover - clover-wheat-maize.

Factor B: organic fertilization: b1 = unfertilized; b2 = manure / 25 t / ha; b3 = manure / 50 t / ha; b4 = lupine; b5= lupine + oats.

Factor C: Annual chemical fertilization: c1 = $N_0P_0K_0$; c2 = $N_{90}P_{60}K_{60}$.

Experimental plot is 40 m^2, and the number of repetitions is four.

The maximum rainfalls registered in Oradea follow the multiannual average values:

X	XI	XII	I	II	III	IV	V	VI	VII	VIII	IX
46.5	49.7	50.3	34.5	38.1	34.1	46.6	61.2	85.3	71.7	56.7	45.3

Yields were calculated by variance analysis method. Water use efficiency was calculated as the ratio between yield and total consumption of water. It was determined by the water balance in the soil method, balance depth being 0-150 cm.

RESULTS AND DISCUSSION

Influence of organic fertilization organo-mineral fertilization on winter wheat yield

In 2014, crop rotation wheat-maize in the second year of effect of organic fertilization (first year effect was on maize) in variant fertilized with 25 t / ha manure registered an yield gain compared with unfertilized by 8.34 q / ha; in variant fertilized with manure 50t / h yield gain was 15.64 q / ha, both being highly statistically significant.

In variant fertilized with lupine pure culture was obtained an yield gain compared to unfertilized variant above the highly statistically significant (4.24 to 4.20 q / ha), while in the variant of lupin + oat was registered a difference compared with unfertilized variant by 7.94 q / ha, similar to the difference obtained through fertilization with manure 25t / ha. (Table 1).

Tabel 1

Influence of fertilization on wheat yield (q / ha) under a sloping land conditions and wheat-maize crop rotation, Oradea 2014

Organic fertilization	Mineral fertilization		Average on organic fertilization
	N_0P_0	$N_{90}P_{60}K_{60}$	
1. Unfertilized	30.12	46.88	38.5^{Mt}
2. Manure 25t/ha	38.46	57.24	47.85^{***}
3. Manure 50t/ha	45.76	64.38	55.07^{***}
4. Lupine	34.24	51.34	42.79^{***}
5. Lupine + oat	38.06	56.98	47.5^{***}
Average on mineral fertilization	37.33^{Mt}	55.36^{***}	-

	Organic fertilization	Mineral fertilization	Organic fertilization x Mineral fertilization	Organic fertilization x Mineral fertilization
$LSD_{5\%}$	1.37	1.64	2.26	2.04
$LSD_{1\%}$	2.52	2.28	3.14	3.46
$LSD_{0.1\%}$	5.86	3.12	4.20	5.58

Using chemical fertilizers on organic agrofunds using fertilization system $N_{90}P_{60}K_{60}$ determined obtaining an yield gain compared with variant without NPK by 18.03 q/ha, very significantly significant. In variant unfertilized using chemical fertilizers has led to a production increase of 16.76 q/ha compared with variant $N_0P_0K_0$, very significantly statistic. In variants organo-mineral fertilized variants yield gain was higher than variant unfertilized $N_0P_0K_0$ and only with organic fertilized variants. The highest

yield of wheat (64.38 q / ha) was obtained in the variant where preemergent plant (maize) were applied 50t/ha manure and was fertilized with $N_{90}P_{60}K_{60}$. Also in this variant, chemical fertilization led and getting the biggest difference compared with organic fertilization (18.62 q / ha) of all 5 variants studied.

In ameliorative crop rotation with clover was obtained a higher level of yield compared with wheat yield obtained in variants with wheat-maize crop rotation:

- in the unfertilized variant, in the first year effect of the presence of clover in rotation determined to obtain an yield gain of 10.06 q / ha;in variant fertiulized with $N_{120}P_{90}K_{90}$ yield gain was 13.08 q / ha. Organic fertilization applied for maize crop had positive effects on wheat yield, yield differences comparing with unfertlized variant being higher than in wheat-maize crop rotation;

- organo-mineral fertilization determined to obtain the highest yields of wheat (Table 2).

Table 2

Influemce of fertilization on wheat yield (q/ha) in the condition of an sloping land of the crop rotation oat+clover-clover-wheat-maize, Oradea 2014

Organic fertilization	Mineral fertilization		Average on organic fertilization
	N_0P_0	$N_{90}P_{60}K_{60}$	
1. Unfertilized	40.18	53.26	46.72^{Mt}
2. Manure 25t/ha	50.26	60.88	55.57^{***}
3. Manure 50t/ha	57.12	68.96	63.04^{***}
4. Lupine	45.36	58.04	51.70^{***}
5. Lupine + oat	49.94	60.12	55.03^{***}
Average on mineral fertilization	48.56^{Mt}	60.25^{***}	

	Organic fertilization	Mineral fertilization	Mineral fertilization x Organic fertilization	Organic fertilization x Mineral fertilization
$LSD_{5\%}$	1.29	1.54	2.42	2.12
$LSD_{1\%}$	2.31	2.21	3.36	3.62
$LSD_{0.1\%}$	5.64	3.28	4.56	5.84

Influence of organic and mineral fertilization on water use efficiency (EVA)

In 2014, in crop rotation wheat - maize, the most reduced efficiency of water use (EVA) was registered in variant unfertilized, 0.74 kg/m^3. Among the organic fertilized variants, in the variant fertilized with lupine pure culture was obtained the lowest value of EVA, 0.84 kg / m^3, in variants fertilized with manure 25 t / ha + oats and lupins were obtained similar values, and the highest value EVA was registered in variant fertilized with manure 50 t / ha. Fertilization with chemical fertilizers increased the value

of water use efficiency in variant chemically fertilized and especially in variant organo-mineral fertilized. (Table 3)

Table 3

Influence of fertilization on water use efficiency (EVA) by wheat crop in the conditions of wheat –maize crop rotation, Oradea 2014

Organic fertilization	N_0P_0		$N_{90}P_{60}K_{60}$	
	Kg/m^3	%	Kg/m^3	%
1. Unfertilized	0.74	100	1.15	100
2. Manure 25t/ha	0.95	128.3	1.41	122.4
3. Manure 50t/ha	1.13	152.7	1.58	137.7
4. Lupine	0.84	113.5	1.26	109.9
5. Lupine + oat	0.94	127.0	1.40	121.9
Average	0.92	100	1.36	147.8

In ameliorative crop rotation with clover were recorded the highest values of water use efficiency. Thus at the unfertilized variant compared to 0.74 kg per 1 m^3 of water used obtained as crop rotation wheat - maize in ameliorative crop rotation were obtained 33.7% (0.99 kg / m^3). In the other variants were regsitered appreciable differences. (Table 4).

Table 4

Influence of fertilization on water use efficiency (EVA) by wheat crop in the conditions of oat+clover-clover- wheat –maize crop rotation, Oradea 2014

Organic fertilization	N_0P_0		$N_{90}P_{60}K_{60}$	
	Kg/m^3	%	Kg/m^3	%
1. Unfertilized	0.99	100	1.31	100
2. Manure 25t/ha	1.24	124.9	1.50	114.3
3. Manure 50t/ha	1.41	134.4	1.70	129.5
4. Lupine	1.13	114.2	1.43	109.0
5. Lupine + oat	1.23	124.1	1.48	112.9
Average	1.20	100	1.48	123.6

In 2015, crop rotation wheat-maize in the third year of effect of organic fertilization (first year effect was on maize) in variant fertilized with 25 t / ha manure registered an yield gain compared with unfertilized by 7.42 q / ha; in variant fertilized with manure 50t / h yield gain was 14.52 q / ha, both being highly statistically significant.

In variant fertilized with lupine pure culture was obtained an yield gain compared to unfertilized variant above the highly statistically significant (2.66 to 2.58 q / ha), while in the variant of lupin + oat was registered a difference compared with unfertilized variant by 7.14 q / ha, very significant statistically, similar to the difference obtained through fertilization with manure 25t / ha. (Table 5).

Table 5

Influence of fertilization on wheat yield (q / ha) under a sloping land conditions and wheat-maize crop rotation, Oradea 2015

Organic fertilization	Mineral fertilization		Average on organic fertilization
	N_0P_0	$N_{90}P_{60}K_{60}$	
1. Unfertilized	35.76	50.12	42.94^{Mt}
2. Manure 25t/ha	43.18	61.90	52.54^{***}
3. Manure 50t/ha	50.28	67.60	58.94^{***}
4. Lupine	38.42	55.26	46.84^{***}
5. Lupine + oat	42.90	60.84	51.87^{***}
Average on mineral fertilization	42.10^{Mt}	59.14^{***}	-

	Organic fertilization	Mineral fertilization	Mineral fertilization x Organic fertilization	Organic fertilization x Mineral fertilization
$LSD_{5\%}$	2.1	1.12	2.58	2.22
$LSD_{1\%}$	3.36	2.24	3.76	3.12
$LSD_{0.1\%}$	6.20	3.76	5.12	4.96

Using chemical fertilizers on organic agrofunds using fertilization system $N_{90}P_{60}K_{60}$ determined obtaining an yield gain compared with variant without NPK by 17.04 q/ha, very significantly significant. In variant unfertilized using chemical fertilizers has led to a production increase of 14.36 q/ha compared with variant $N_0P_0K_0$, very significantly statistic. In variants organo-mineral fertilized variants yield gain was higher than variant unfertilized $N_0P_0K_0$ and only with organic fertilized variants. The highest yield of wheat (67.60 q / ha) was obtained in the variant where preemergent plant (maize) were applied 50t/ha manure and was fertilized with $N_{90}P_{60}K_{60}$. Also in this variant, chemical fertilization led and getting the biggest difference compared with organic fertilization of all 5 variants studied.

In ameliorative crop rotation with clover was obtained a higher level of yield compared with wheat yield obtained in variants with wheat-maize crop rotation:

- in the unfertilized variant, in the first year effect of the presence of clover in rotation determined to obtain an yield gain of 9.48 q/ha; in variant fertilized with $N_{120}P_{90}K_{90}$ yield gain was 22.6 q/ha.

- organo-mineral fertilization determined to obtain the highest yields of wheat (Table 6).

Table 6

Influence of fertilization on wheat yield (q / ha) under a sloping land conditions and oat+clover-clover-wheat-maize crop rotation, Oradea 2015

Organic fertilization	Mineral fertilization		Average on organic fertilization
	N_0P_0	$N_{90}P_{60}K_{60}$	
1. Unfertilized	45.24	58.36	51.8^{Mt}
2. Manure 25t/ha	55.72	64.60	60.16^{***}
3. Manure 50t/ha	62.40	71.04	66.72^{***}
4. Lupine	50.08	60.12	55.10^{***}
5. Lupine + oat	54.76	63.94	59.35^{***}
Average on mineral fertilization	53.64^{Mt}	63.61^{***}	-

	Organic fertilization	Mineral fertilization	Mineral fertilization x Organic fertilization	Organic fertilization x Mineral fertilization
$LSD_{5\%}$	2.1	1.47	2.88	2.45
$LSD_{1\%}$	3.2	2.14	3.78	3.58
$LSD_{0.1\%}$	5.32	3.88	5.34	4.96

In 2015, in crop rotation wheat - maize, the most reduced efficiency of water use (EVA) was registered in variant unfertilized, 0.82 kg/m^3. Among the organic fertilized variants, in the variant fertilized with lupine pure culture was obtained the lowest value of EVA, 0.89 kg / m^3, in variants fertilized with manure 25 t / ha + oats and lupins were obtained similar values, and the highest value EVA was registered in variant fertilized with manure 50 t / ha. Fertilization with chemical fertilizers increased the value of water use efficiency in variant chemically fertilized and especially in variant organo-mineral fertilized. (Table 7).

Table 7

Influence of fertilization on water use efficiency (EVA) by wheat crop in the conditions of wheat –maize crop rotation, Oradea 2015

Organic fertilization	N_0P_0		$N_{90}P_{60}K_{60}$	
	Kg/m^3	%	Kg/m^3	%
1. Unfertilized	0.82	100	1.16	100
2. Manure 25t/ha	0.99	121	1.43	123
3. Manure 50t/ha	1.15	141	1.56	134
4. Lupine	0.89	108	1.25	108
5. Lupine + oat	0.99	121	1.40	121
Average	0.97	100	1.36	140

In ameliorative crop rotation with clover were registered the highest values of water use efficiency. Thus at the unfertilized variant compared to 0.82 kg per 1 m^3 of water used obtained as crop rotation wheat - maize in ameliorative crop rotation were obtained with 26.8% (0.99 kg / m^3) more. In the other variants were regsitered appreciable differences. (Table 8).

Table 8

Influence of fertilization on water use efficiency (EVA) by wheat crop in the conditions of oat+clover-clover-wheat –maize crop rotation, Oradea 2015

Organic fertilization	N_0P_0		$N_{90}P_{60}K_{60}$	
	Kg/m^3	%	Kg/m^3	%
1. Unfertilized	1.04	100	1.35	100
2. Manure 25t/ha	1.28	123	1.50	110
3. Manure 50t/ha	1.44	138	1.64	121
4. Lupine	1.15	111	1.39	103
5. Lupine + oat	1.26	121	1.47	109
Average	1.23	100	1.47	120

In 2016, the drought has led to the achievement of small yields. In crop rotation wheat-maize yields obtained were lower than yields obtained in crop rotation oats + clover - clover - wheat - maize both in terms of organic fertilizer and organic-mineral fertilizer. În both crop rotations highest wheat yields were obtained in the variant with manure 50 t / ha (applied corn crop) and $N_{90}P_{60}K_{60}$ annual mineral fertilizer. In variant fertilized with lupine + oat yields obtained were closely with yield obtained in variant fertilized with manure 25 t / h (table 9; 10).

Table 9

Influence of fertilization on wheat yield (kg / ha) under a sloping land conditions and wheat-maize crop rotation, Oradea 2016

Organic fertilization	Mineral fertilization		Average on organic fertilization
	N_0P_0	$N_{90}P_{60}K_{60}$	
1. Unfertilized	1720	2790	2255^{Mt}
2. Manure 25t/ha	2510	3640	3075^{xxx}
3. Manure 50t/ha	3420	4350	3885^{xxx}
4. Lupine	1980	2880	2430^{xxx}
5. Lupine + oat	2490	3520	3005^{xxx}
Average on mineral fertilization	2424^{Mt}	3436^{xxx}	

	Organic fertilization	Mineral fertilization	Mineral fertilization x Organic fertilization	Organic fertilization x Mineral fertilization
LSD 5%	190	130	260	240
LSD 1%	320	260	410	380
LSD 0,1%	580	390	630	570

Tabel 10

Influence of fertilization on wheat yield (kg/ ha) under a sloping land conditions and oat+clover-clover-wheat-maize crop rotation, Oradea 2016

Organic fertilization	Mineral fertilization		Average on organic fertilization
	N_0P_0	**$N_{90}P_{60}K_{60}$**	
1. Unfertilized	2610	3570	3090^{Mt}
2. Manure 25t/ha	3420	4380	3900^{xxx}
3. Manure 50t/ha	4230	5020	4625^{xxx}
4. Lupine	2990	3980	3485^{xxx}
5. Lupine + oat	3380	4400	3890^{xxx}
Average on mineral fertilization	3326	4270	-

	Organic fert.	Mineral fertilization	Min. fert.. x Org. fert.	Fert. org. x min fert.
LSD 5%	210	170	290	250
LSD 1%	360	290	450	410
LSD 0,1%	590	470	670	610

Water used efficiency had higher values in rotation with clover compared with crop rotation with wheat - maize, at 1m^3 of water consumed to give a larger amount of wheat seed. Meaning differences between variants is similar to thatregistered in the case of wheat yield (table 11; 12).

Table 11

Influence of fertilizations on water use efficiency (EVA) by winter wheat crop in the condition of sloping land and crop rotation wheat-maize, Oradea 2016

Organic fertilization	EVA			
	N_0P_0		$N_{90}P_{60}K_{60}$	
	kg/m^3	%	kg/m^3	%
1. Unfertilized	0.72	100	1.16	100
2. Manure 25t/ha	1.05	145	1.52	131
3. Manure 50t/ha	1.43	197	1.81	157
4. Lupine	0.80	115	1.20	103
5. Lupine + oat	1.04	144	1.47	126
Average	1.01	100	1.43	141.7

Table 12

Influence of fertilizations on water use efficiency (EVA) by winter wheat crop in the condition of sloping land and crop rotation oat+clover-clover-wheat-maize, Oradea 2016

Organic fertilization	EVA			
	N_0P_0		$N_{90}P_{60}K_{60}$	
	kg/m^3	%	kg/m^3	%
1. Unfertilized	1.09	100	1.49	100
2. Manure 25t/ha	1.43	131	1.83	122
3. Manure 50t/ha	1.76	162	2.09	140
4. Lupine	1.25	115	1.66	111
5. Lupine + oat	1.41	129	1.83	122
Average	1.39	100	1.78	128

CONCLUSIONS

Crop rotation and fertilization have an important role in agrotechnics erosion. The research was conducted in 2014-2016 at Agricultural Research and Development Station Oradea on a land with a slope of 10% and took into account the study of the influence of two types of crop rotation (wheat, maize, oats + clover - clover - wheat - maize) on wheat yield and on water used efficiency of wheat crop.The research was conducted under 4 graduations organic fertilizer (unfertilized, manure 25 t/ha, manure 50 t/ha,

lupine and lupine + oats) and two graduations of mineral fertilization (N_0P_0; $N_{90}P_{80}K_{60}$)

The results obtained in the period 2014-2016 shows that the highest yields of wheat were obtained under the conditions where the preemergent plant was clover, rather than maize.

Organic fertilization (used in maize crop) associated with mineral fertilization determined obtaining of higher wheat yield compared with only organic fetilization. The highest yields were obtained in the variant with manure 50 t / ha + $N_{90}P_{80}K_{60}$.

Lupine as green manure incorporated into the soil for maize crop determined obtaining of higher gain yield statistically assured compared with variant unfertilized but lower than the gain yield obtained by using manure 25 t / ha.

Using of lupine + oat mixture as green manure determined obtaining of higher gain yields statistically assured comparing with lupine pure culture and close to the yields obtained in the variant fertilized with manure 25 t / ha.

In the crop rotation with clover, has improved the water use efficiency by wheat as compared to wheat-maize crop rotation.

The highest values of water use efficiency were registered in variants organo-mineral fertilized.

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